LONDON-WEST MIDLANDS ENVIRONMENTAL STATEMENT

Volume 5 | Technical Appendices

CFA3 | Primrose Hill to Kilburn (Camden)

Flood risk assessment (WR-003-003)

Water resources

November 2013

VOL 5

ES 3.5.2.3.13

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Department for Transport

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1 Introduction

1.1 Structure of the water resources and flood risk assessment appendices

1.1.1 The water resources and flood risk assessment appendices comprise three parts. The first of these is a route-wide appendix (Volume 5: Appendix WR-001-000).

1.1.2 Specific appendices for each community forum area (CFA) are also provided. For the Primrose Hill to Kilburn (Camden) area (CFA3) these are:

- a water resources assessment (Volume 5: Appendix WR-002-003); and
- a flood risk assessment (i.e. this appendix).

1.1.3 Maps referred to throughout the water resources and flood risk assessment appendices are contained in the Volume 5, Water Resources and Flood Risk Assessment Map Book.

1.2 Scope and structure of this assessment

1.2.1 This flood risk assessment (FRA) considers the assessment of flood risk in CFA3. The assessment has been carried out in accordance with the requirements of the National Planning Policy Framework (NPPF)[1] which aims to prevent inappropriate development in areas at risk of flooding and to ensure that, where development is necessary in areas at risk of flooding, it is safe without increasing flood risk elsewhere.

1.2.2 The FRA methodology and a review of the relevant local planning policy documents are provided in Section 2 of this report. The design criteria are provided in Section 3 and Section 4 documents the sources of information that have been reviewed. Section 5 provides a description of the planned works within CFA3. Section 6 considers baseline flood risk and the risk of flooding to the Proposed Scheme from all relevant sources. Flood risk mitigation measures included within the Proposed Scheme are detailed in Section 7. The effect of the Proposed Scheme on the risk of flooding is considered in Section 8.

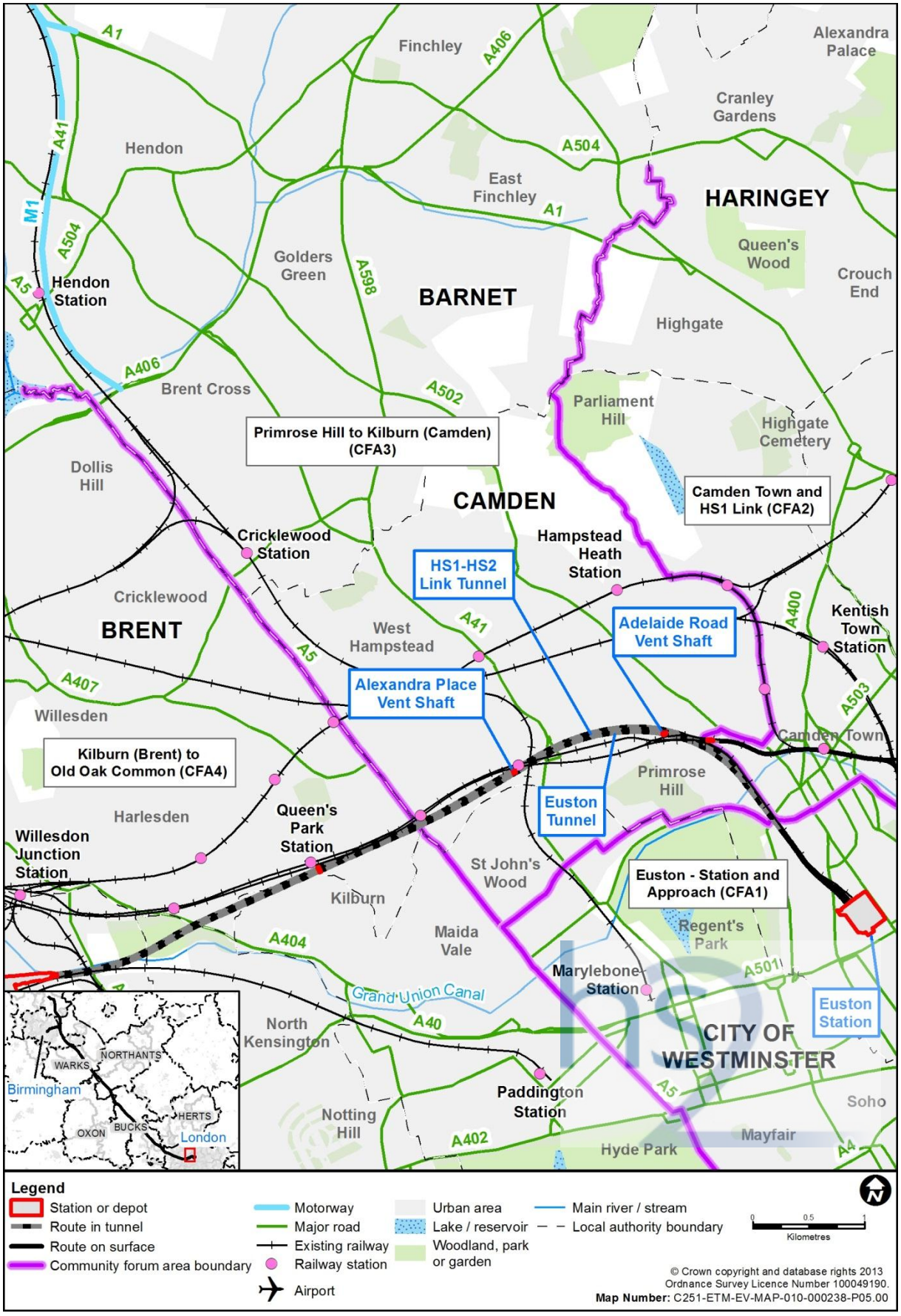
1.3 Location

1.3.1 CFA3 covers a 3.6km section of the Euston Tunnel (twin-bore tunnel) and a 2.7km section of the HS1-HS2 Link tunnel (a single-bore tunnel). The route of these tunnels passes to the west of Camden Town, to the north of Primrose Hill and south of Swiss Cottage.

1.3.2 The study area extends to a distance of 500m from the centre line of the route. The Euston - Station and Approach area (CFA1) lies to the south, the Camden Town and HS1 Link area (CFA2) lies to the east and the Kilburn (Brent) to Old Oak Common area (CFA4) lies to the west, as shown in Figure 1. The route will cross the Grand Union Canal (Regent's Canal).

[1] Department for Communities and Local Government (2012), *National Planning Policy Framework.*

Figure 1: Primrose Hill to Kilburn (Camden) area



2 Flood risk assessment methodology

2.1 Source-pathway-receptor model

2.1.1 Flood risk is assessed using the source-pathway-receptor model. In this model, individual sources of flooding within the study area are identified. The primary source of flooding is rainfall which is a direct source in the short-term (direct surface water runoff) and can lead to flooding from watercourses (river flooding) and overloaded man-made collection systems (sewers) in the short or medium-term. Stored rainfall, either naturally in below ground aquifers and natural lakes or artificially in impounded reservoirs and canals, can lead to flooding when the storage capacity of the system is exceeded. A final source of flooding arises from tidal effects and storm surges caused by low pressure systems over the sea.

2.1.2 For there to be a risk of flooding at an individual receptor there must be a pathway linking it to the source of flooding. The pathways within the study area are assessed by reviewing national datasets that show the spatial distribution of flood risk. The associated risk magnitude is then categorised.

2.1.3 Receptors considered in this assessment include the Proposed Scheme and existing development within 500m of the Proposed Scheme. The Proposed Scheme includes all associated permanent infrastructure. Areas of interest are identified through comparison of the national spatial datasets with the design drawings. Where a risk is identified mitigation is proposed in line with recommendations in the NPPF.

2.1.4 Existing receptors within the study area are identified using Ordnance Survey (OS) mapping information. A high-level screening assessment is then undertaken to identify receptors that are within or in close proximity to an area of flood risk via pathways indicated using the flood risk data sources listed below. The vulnerability of each receptor is classified using Table 2 of the NPPF Technical Guidance Document[2].

2.1.5 The assessment then considers the vulnerability of the receptor with reference to the flood risk category of the source using Table 3 of the NPPF Technical Guidance Document and assesses whether the Proposed Scheme has any potential to influence or alter the risk of flooding to each receptor. Where such potential has been identified, mitigation is proposed based on further analysis.

2.2 Flood risk categories

2.2.1 The level of flood risk is categorised by assessing the design elements against the datasets for each source. A matrix showing the flood risk category associated with each flooding source is presented in Table 1.

[2] Department for Communities and Local Government (2012), *National Planning Policy Framework Technical Guidance.*

Table 1: Flood risk category matrix for all flooding sources

Source of flooding	Flood risk category				
	No risk	**Low**	**Medium**	**High**	**Very high**
Rivers		Flood Zone 1	Flood Zone 2	Flood Zone 3a	Flood Zone 3b
Surface water	No surface water flooding.	Surface water flooding <0.3m for 1 in 200 years event.	Surface water flooding >0.3m for 1 in 200 years event; and Surface water flooding <0.3m for 1 in 30 years event.	Surface water flooding >0.3m for 1 in 30 years event.	
Groundwater		Very low-low	Moderate	High-very high	
Drainage and sewer systems	No sewer in vicinity of site.	Surcharge point >20m from site and no pathways.	Surcharge point within 20m of site and restricted pathways.	Sewer network crosses site and pathways exist.	
Artificial sources	Outside of inundation mapping/no pathway exists.	Within inundation mapping/ pathway exists.			

2.3 Regional and local flooding planning policy documents

2.3.1 The lead local flood authority (LLFA) and local planning authority for CFA3 is the London Borough of Camden (LBC). The recommendations from the LBC Preliminary Flood Risk Assessment (PFRA)[3] have been reviewed in undertaking this assessment. The LBC Local Flood Risk Management Strategy (LFRMS)[4] was approved in June 2013.

2.3.2 LBC has also produced a strategic flood risk assessment (SFRA)[5] in conjunction with a number of surrounding local planning authorities .

London Borough of Camden Preliminary Flood Risk Assessment

2.3.3 The LBC PFRA indicates that there have been no identifiable past floods in the borough that have had significant harmful consequences. Future flood risk in the borough is, however, estimated to be high based on the Drain London surface modelling outputs.

2.3.4 The LBC PFRA confirms that the entire extent of the borough lies within the indicative flood risk area and that no modifications to the outline are required. Further stages of the Flood Risk Regulations 2009[6] process (i.e. flood risk mapping and flood risk management plans) will therefore be undertaken in due course. The LBC PFRA states

[3] Halcrow (2011), *London Borough of Camden Preliminary Flood Risk Assessment*.
[4] London Borough of Camden (2013), *Managing flood risk in Camden: The Camden flood risk management strategy*.
[5] Mouchel (2008), *North London Strategic Flood Risk Assessment*. North London Waste Authority.
[6] *Flood Risk Regulations 2009* (SI 2009 No. 3042), London, Her Majesty's Stationery Office.

that the current locally agreed spatial surface water flood risk information dataset is from the modelling activities undertaken as part of the Drain London project.

London Borough of Camden Local Flood Risk Management Strategy

2.3.5 The LBC LFRMS guides the planning process in relation to flood risk across all categories and outlines key policies in relation to development within the LBC area. The strategy aims:

- to understand and explain the level of risk affecting the residents and businesses of Camden;
- to provide an action plan for areas at particular risk from surface water flooding;
- to highlight the actions that all partners, businesses and residents in Camden should be taking to manage flood risk; and
- to take a sustainable and holistic approach to flood management in seeking to deliver wider environmental and social benefits.

Thames Region Catchment Flood Management Plan

2.3.6 The Thames Region Catchment Flood Management Plan (CFMP)[7] sets out policies for the sustainable management of flood risk across the Thames catchment over the coming 50-100 years taking climate change into account. CFA3 lies within the TE2100 Policy Unit, and the preferred policy is Policy 4. This includes areas of low, moderate or high risk where the Environment Agency is already managing the flood risk effectively but where further action may need to be taken to keep pace with climate change.

2.3.7 The Thames Region CFMP states that the most sustainable approach to managing future flood risk will be to bring about adaptation of the urban environment. It indicates that strategic scale planning is key to achieving the needs of the community and managing flood risk in a more sustainable way and that emergency planning is integral to the approach to managing extreme flood events.

London Regional Flood Risk Appraisal

2.3.8 The London Regional Flood Risk Appraisal (RFRA)[8] provides a broad regional understanding of the risk of flooding in Greater London to feed into each of the LLFA SFRA and PFRA reports. Recommendation 7 states that regeneration and redevelopment of London's river corridors offers a crucial opportunity to reduce flood risk in these areas.

North London Strategic Flood Risk Assessment

2.3.9 The North London SFRA was completed in 2008 as part of the evidence base for the North London Waste Plan. LBC is one of seven participating boroughs included in the report. The North London SFRA states that LBC has a particularly high risk of flooding

[7] Environment Agency (2008), *Thames Catchment Flood Management Plan.*
[8] Greater London Authority (2009), *London Regional Flood Risk Appraisal.*

from sewer and surface water sources while river flood risk remains low due to the lack of watercourses.

London Borough of Camden Core Strategy

2.3.10 Policy CS13 of the LBC adopted Core Strategy[9] seeks to make Camden a water efficient borough and minimise the potential for surface water flooding by requiring development to avoid harm to the water environment, water quality or drainage systems. Development should also aim to prevent or mitigate local surface water and down-stream flooding, especially up-hill from and in areas known to be at risk from surface water flooding.

London Borough of Camden Adopted Development Policies

2.3.11 Policy DP23 of the LBC adopted Development Policies[10] requires that developments reduce their water consumption and the risk of flooding by:

- incorporating water efficient features and equipment;
- limiting the amount and rate of runoff and waste water to reduce the risk of flooding;
- reducing the pressure placed on the storm water and sewer network; and
- ensuring that development is assessed for upstream and downstream groundwater flood risks in areas where historic underground streams are known to have been present.

2.3.12 Policy DP23 requires all new developments in areas identified as having a risk of surface water flooding in the LBC to achieve a greenfield rate of runoff. All other development that increases the amount of impervious surface is expected to minimise the amount and rate of runoff from the site to at least the existing rate. The Proposed Scheme will pass through areas that are identified as having historically flooded within LBC during the 1975 and 2002 events. It will, however, not pass through areas with the potential to be at risk of surface water flooding as shown in Map 2 within the LBC adopted Development Policies document.

2.3.13 Policy DP22 requires development to be resilient to climate change by ensuring schemes include appropriate adaptation measures such as limiting runoff and reducing water consumption.

[9] London Borough of Camden (2010), *Adopted Core Strategy*.
[10] London Borough of Camden (2010), *Adopted Development Policies*.

3 Design criteria

3.1.1 It is a requirement of the design that the Proposed Scheme shall be protected against flooding from any source during the 1 in 1,000 years return period (0.1% annual probability) rainfall event, with water levels not rising closer than 1m to the top of rail level.

3.1.2 In accordance with the NPPF, an allowance for climate change is included in the assessment by assuming that peak rainfall intensity will increase by 30% and that peak river flows will increase by 20%.

4 Data sources

4.1 Primary datasets

4.1.1 Consistent with the requirements of the NPPF, this assessment considers the risk of flooding from rivers, overland flow (surface water), rising groundwater, overwhelmed drainage and sewer systems, and artificial sources such as reservoirs, lakes and canals.

4.1.2 The Proposed Scheme lies entirely outside the extent of flooding from the sea and therefore the risk of flooding from tidal sources is not considered in this assessment.

4.1.3 The primary datasets for each source of flooding used to assess the design elements are presented in Table 2. A high-level review of the risk of flooding and potential impacts is undertaken on the basis of these datasets across all flood sources. Where this review indicates potentially significant impacts on the risk of flooding, or a risk of flooding to the line, further investigation in the form of hydraulic modelling is undertaken.

Table 2: Flood risk assessment data sources

Source of flooding	Datasets reviewed	Data owner
Rivers	Flood zone mapping. Detailed River Network. Catchment hydraulic models.	Environment Agency
Surface water	Flood Map for Surface Water (FMfSW). Local surface water flood mapping.	Environment Agency LLFA
Groundwater	Areas susceptible to groundwater flooding. 1:50,000 geological mapping (superficial and bedrock). Potential for elevated groundwater.	British Geological Survey LLFA
Drainage and sewer systems	Sewer network plans. Lost river location plans.	Thames Water Utilities Limited (TWUL) Local planning authority
Artificial sources	Reservoir inundation mapping. Canal infrastructure locations. Trunk water main asset plans.	Environment Agency Canal & River Trust TWUL

4.2 Site familiarisation visits

4.2.1 No site familiarisation visits were undertaken within CFA3.

5 The proposed development

5.1 Topography and land use

5.1.1 The topography of the study area within CFA3 is generally flat with the exception of Primrose Hill. The area is predominantly urban in character and includes the urban centres of Primrose Hill, St John's Wood and South Hampstead.

5.1.2 The Grand Union Canal (Regent's Canal) flows in a north-west to south-east direction from Fitzroy Bridge to Prince Albert Bridge in the south-east corner of the study area. Primrose Hill, which provides approximately 25ha of informal open space, is located approximately 225m to the south of the Proposed Scheme.

5.1.3 The West Coast Main Line (WCML) from Euston Station is on a north-west to south-east axis through the study area. The North London Line (NLL), which forms part of the London Overground (LO) network, follows the route of the WCML. The London Underground (LU) Metropolitan and Jubilee Lines also run through the study area with stations at Finchley Road, Swiss Cottage and St John's Wood.

5.2 Local flood risk receptors

5.2.1 The vulnerability of each local receptor with an identified pathway within the study area is presented in Table 3. The vulnerability is classified in accordance with the recommendations of Table 2 in the NPPF Technical Guidance Document and the Scope and Methodology Report (SMR) (see Volume 5: Appendix CT-001-000/1) and the SMR Addendum (see Volume 5: Appendix CT-001-000/2).

Table 3: Vulnerability of local receptors in CFA3

Local receptor	Description	Vulnerability classification	Source/pathway
Primrose Hill urban centre	Residential dwellings and associated infrastructure	More vulnerable	Surface water 30 years - deep
WCML and LO	Railway corridor	More vulnerable	Surface water 200 years - deep
South Hampstead urban centre	Residential dwellings and associated infrastructure	More vulnerable	Surface water 200 years - deep
South Hampstead Station	Railway infrastructure	More vulnerable	Surface water 200 years - deep
Quintin Kynaston School	Educational establishment	More vulnerable	Surface water 30 years - shallow
St John's Wood urban centre (north)	Residential dwellings and associated infrastructure	More vulnerable	Surface water 200 years - shallow

5.3 Description of the Proposed Scheme

5.3.1 The Proposed Scheme through this area will be entirely in tunnel comprising the twin-bore Euston tunnel and the single-bore HS1-HS2 Link tunnel. Design elements within

CFA3 are identified on Map CT-06-003 to Map CT-06-006 (Volume 2, CFA3 Map Book).

5.3.2 The route of the Euston tunnel through the area will commence from the boundary of the CFA1 south of A4201 Parkway, between Mornington Terrace and Park Village East. The route will then proceed north-west connecting with the new be ventilation and intervention shafts (vent shafts) at the B509 Adelaide Road, just east of the junction with Primrose Hill Road (see Map CT-06-004, C6 (Volume 2, CFA3 Map Book); and at Alexandra Place, located immediately west of Loudoun Road (see Map CT-06-005, B6 (Volume 2, CFA3 Map Book)). The route will leave CFA3 to the west in tunnel at the A5 Kilburn High Road.

5.3.3 The HS1-HS2 Link tunnel will also run through CFA3. The single-bore tunnel will commence at the boundary with CFA2, beneath Regent's Park Road Bridge. The tunnel will continue west for approximately 330m before aligning with the Euston tunnel at the Adelaide Road vent shaft. From here the HS1-HS2 Link tunnel will run parallel with and between the twin-bore Euston tunnel before leaving CFA3 at the A5 Kilburn High Road.

5.3.4 Camden carriage sidings, existing WCML sidings located off Gloucester Avenue, will be extended as part of the Proposed Scheme to increase the number of conventional 12-car trains that can be stabled there during the construction period and during operation. Reconfiguration of the existing conventional railway tracks north of the A4201 Parkway is also required as well as the removal and partial realignment of some of the tracks serving the NLL west of Regent's Park Bridge.

6 Existing flood risk

6.1 Historical flooding incidents

6.1.1 The Camden PFRA did not identify any past floods within the study area that have had significant harmful consequences and that would be reportable to the European Union.

6.1.2 The North London SFRA reports that a large area in the north of Camden was affected by surface water flooding in August 2002 as a result of heavy rainfall inundating the public sewer system. A similar area of Camden was affected by surface water and sewer flooding in 1975. Flooding during both events was experienced in the area immediately north and east of South Hampstead Station.

6.1.3 A retaining wall collapsed onto the track on the approach to Euston Station during the 2002 flooding event and caused a closure of the station[11]. The LBC Geological Study notes that the Primrose Hill tunnel flooded during the 2002 event[12].

6.1.4 The Camden PFRA states that sewer flooding occurred within the borough in August 2004, September 2005 and July 2007. Specific locations of these flood incidents are not provided in the document.

6.1.5 The North London SFRA reports that no groundwater flooding incidents have been recorded by the Environment Agency in Camden.

6.2 Risk of flooding from rivers

6.2.1 The Proposed Scheme will not cross any Environment Agency designated main rivers or ordinary watercourses within CFA3 and the entire study area is within Flood Zone 1.

6.3 Risk of flooding from surface water

6.3.1 The Drain London modelling outputs and the Environment Agency FMfSW have been reviewed to form the basis of the assessment of the risk of surface water flooding. The LBC PFRA shows a good correlation between the FMfSW and the Drain London modelling. The Drain London modelling considers the underground drainage infrastructure in a higher level of detail and is considered to be the superior dataset. The FMfSW for the 1 in 200 years return period (0.5% annual probability) rainfall event is shown on Map WR-01-003 (Volume 5, Water Resources and Flood Risk Assessment Map Book).

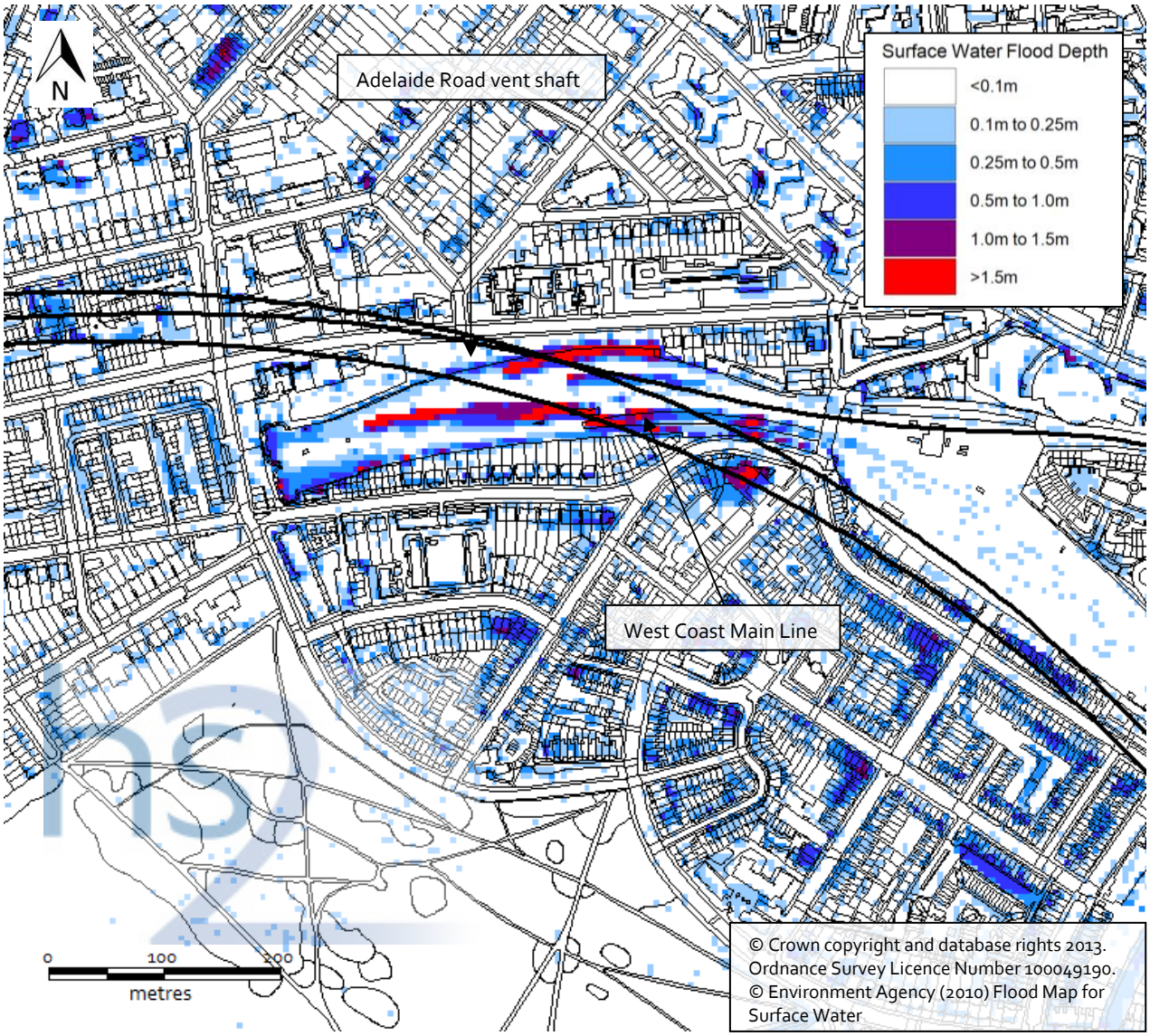
6.3.2 There are areas within the study area that have a high risk of surface water flooding. Since the route will be within tunnel for the majority of the CFA the risk of surface water flooding has been considered only in the location of permanent above-ground infrastructure.

[11] London Borough of Camden (2003), *Floods in Camden: Report of the Floods Scrutiny Panel.*
[12] ARUP (2010), *London Borough of Camden Geological Study.*

Adelaide Road vent shaft

6.3.3 Surface water flooding datasets from the LBC PFRA show parts of the rails of the WCML and LO lines between Euston Station and South Hampstead Station to be at risk of flooding during the 1 in 200 years return period (0.5% annual probability) flood event to a depth greater than 1.5m, as shown in Figure 2. The Adelaide Road vent shaft will be located to the north of the WCML approximately 15m from the closest area at risk of surface water flooding, as shown on Map CT-06-004, C6 (Volume 2, CFA3 Map Book).

Figure 2: 1 in 200 years return period (0.5% annual probability) surface water flood depth at the Adelaide Road vent shaft from Drain London dataset



6.3.4 The ground level at the location of the vent shaft is around 43.1m above Ordnance Datum (AOD) at Adelaide Road and 37.7m AOD at the existing retaining wall to the north of the WCML. Based on light detection and ranging (LiDAR) information the rail level of the adjacent WCML and LO lines is approximately 32.7m AOD and is more than 5m below adjacent ground levels. The threshold level for the proposed shaft will be 41.0m AOD on the southern side. There will, therefore, be a freeboard of at least

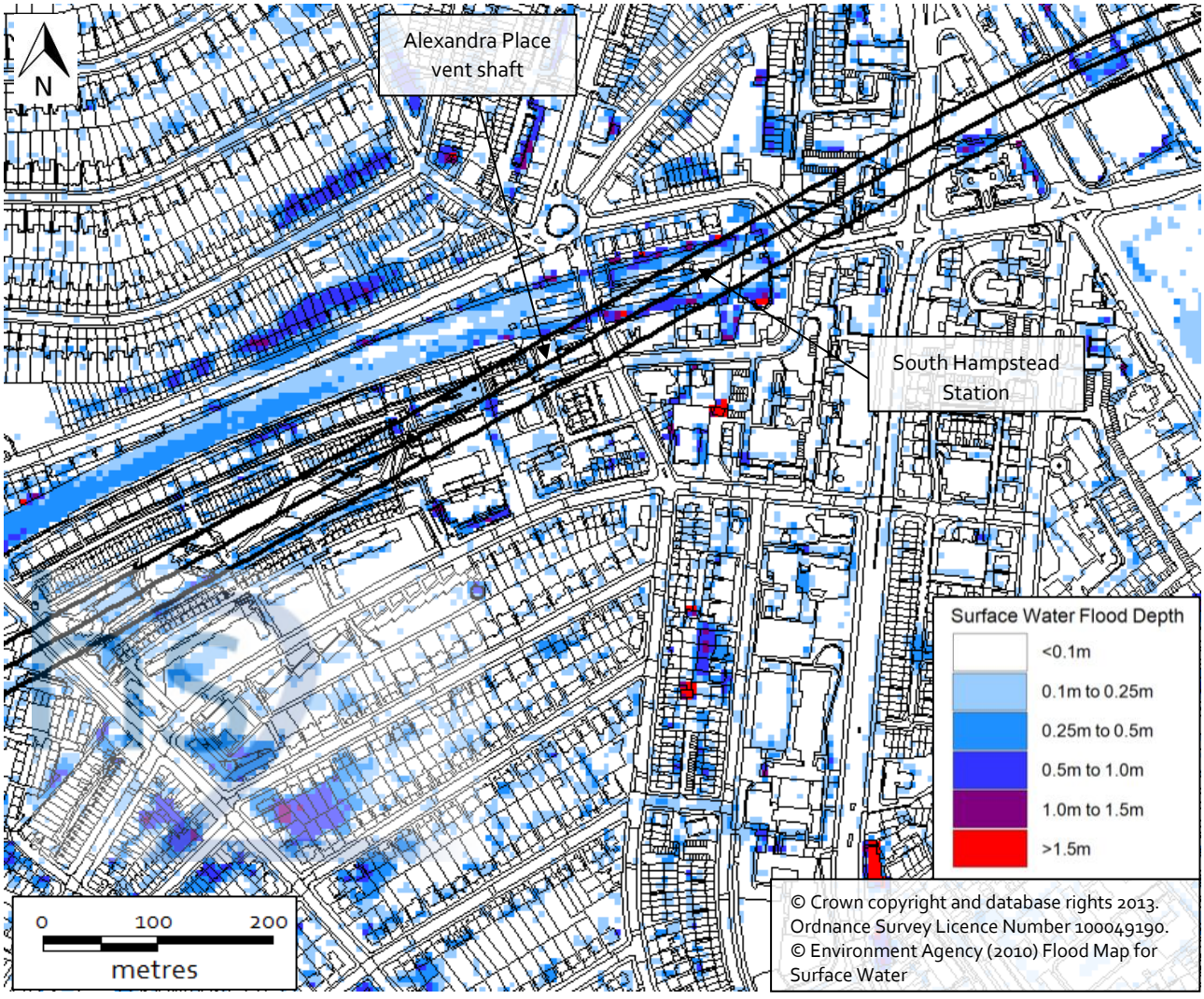
6.8m between the 1 in 200 years return period (0.5% annual probability) flood water level and the minimum threshold level of the vent shaft at this location. Significant depths of surface water flooding are not predicted along Adelaide Road itself.

6.3.5 There will be no significant risk of surface water flooding to the Proposed Scheme at the Adelaide Road vent shaft.

Alexandra Place vent shaft

6.3.6 The surface water flooding datasets from the LBC PFRA show parts of the WCML and LO at South Hampstead Station to be at risk of flooding during the 1 in 200 years return period (0.5% annual probability) flood event as shown in Figure 3. The maximum predicted depth of surface water flooding is less than 0.5m with isolated areas shown to be at risk of surface water flooding to a depth of 1.5m. The Alexandra Place vent shaft will be located to the south of the WCML approximately 15m from the closest area at risk of surface water flooding, as shown on Map CT-06-006, J6 (Volume 2, CFA3 Map Book).

Figure 3: 1 in 200 years return period (0.5% annual probability) surface water flood depth at Alexandra Place vent shaft from Drain London dataset



6.3.7 The approximate ground level is about 40.2m AOD from a measurement along Rowley Way that is located on the boundary of the Alexandra Place vent shaft. Based on LiDAR information the rail level of the adjacent WCML and LO lines is approximately 32.9m AOD and is more than 5m below adjacent ground levels. The threshold level for the proposed shaft is 39.0m AOD on the northern side. There will, therefore, be a freeboard of at least 4.6m between the 1 in 200 years return period (0.5% annual probability) flood water level and the minimum threshold level of the vent shaft at this location.

6.3.8 There will be no significant risk of surface water flooding to the Proposed Scheme at the Alexandra Place vent shaft.

6.4 Risk of flooding from groundwater

6.4.1 Geological mapping indicates that there are no superficial deposits present within the study area. The geological succession beneath the London Clay comprises:

- the Harwich Formation;
- the Lambeth Group;
- the Thanet Sand Formation; and
- the Cretaceous Chalk Group.

6.4.2 The LBC PFRA does not identify any locations that have an increased potential of elevated groundwater within the study area.

6.4.3 There will be no significant risk of groundwater flooding to the Proposed Scheme within CFA3.

6.5 Risk of flooding from drainage systems

6.5.1 The route will pass in tunnel beneath a number of urban centres within the study area. Above ground infrastructure will, therefore, be located close to the existing public sewer network and associated manholes. The LBC PFRA and North London SFRA report a number of historical incidents of sewer flooding. The exact location of these incidents, however, is not available.

6.5.2 The Middle Level Sewer No.2 is a storm relief sewer that conveys storm flows from north London to Beckton Sewage Treatment Works. In addition to passing close to the existing public sewer network the Proposed Scheme will pass beneath the Middle Level Sewer No. 2 in tunnel on the approach to Euston Station.

6.5.3 The Proposed Scheme will pass in tunnel beneath the culverted course of the 'lost' River Tyburn to the east of South Hampstead Station. At this location the river is contained within the combined sewer network that now forms part of the King's Scholars' Pond Sewer, which continues through Marylebone, Bond Street, and Buckingham Palace, discharging to the River Thames in Pimlico.

6.5.4 The Proposed Scheme will also pass beneath two historic tributaries of the River Westbourne to the east of Kilburn High Road Station. The River Westbourne

continues as the Ranelagh storm relief sewer through Paddington and Hyde Park, discharging to the River Thames near Chelsea Bridge.

6.5.5 The sewerage network in this area is predominantly combined and therefore the risk of flooding from sewers is comparable to the risk of flooding from surface water sources as described in Section 6.2 of this report. The large diameter trunk sewers and storm relief sewers will be assessed during detailed design to determine their structural stability prior to commencement of tunnelling works. Any mitigation required to prevent the collapse of the sewers will be installed prior to tunnelling.

6.5.6 There will therefore be no significant risk of flooding from drainage and sewer systems to the Proposed Scheme within CFA3 further to the risk from surface water sources described in Section 6.2 of this report.

6.6 Risk of flooding from artificial sources

Canals

6.6.1 The Proposed Scheme will pass beneath the Grand Union Canal (Regent's Canal) at the southern extent of the study area (SWC-CFA3-01), as shown on Map WR-01-003, G6 (Volume 5, Water Resources and Flood Risk Assessment Map Book). The canal is at or below ground level at the intersection with the Proposed Scheme which will be in twin bored tunnels approximately 25m below ground level. There is no other permanent above ground infrastructure proposed close to the Grand Union Canal (Regent's Canal). As the canal is at ground level there will be no risk of water from the canal escaping to the surface. There will be no risk of flooding to the Proposed Scheme from the Grand Union Canal (Regent's Canal).

Reservoirs

6.6.2 There are no areas within the study area that are shown to have a residual risk of flooding from failure of impounded reservoirs.

Water Mains

6.6.3 The Proposed Scheme will pass beneath a number of TWUL water supply mains within CFA3. Two water mains are identified as being within the carriageway of the A4201 Parkway at the boundary between CFA3 and CFA1, the diameters of which are both 914mm. There are no excavations proposed within CFA3 in the vicinity of these water mains. The Euston tunnel portal will lie approximately 120m to the south. The portal, however, is within CFA1 and is therefore considered in the CFA1 FRA (Volume 5: Appendix WR-003-001). Flooding of the portal could ultimately result in flooding occurring within the tunnels. The FRA for CFA1 will assess whether any such flooding is possible. There is therefore no risk of flooding to the Proposed Scheme within CFA3 from this source.

6.6.4 There are four trunk water supply mains identified on TWUL records along the A41 Avenue Road and the B511 Finchley Road near to South Hampstead Station with diameters of 1067mm, 406mm, and two of 381mm. The Alexandra Place vent shaft will be located approximately 350m to the west of the water mains. The ground level at the location of the water mains is approximately 54m AOD and the ground level at

the Alexandra Place vent shaft is approximately 40m AOD. Any flooding arising from failure of these water mains would potentially flow down-gradient along Hilgrove Road and Alexandra Road towards the Alexandra Place vent shaft. The WCML cutting at South Hampstead Station, however, lies on the direct pathway between the source of flooding and the Alexandra Place vent shaft and is set below ground at around 35m AOD. It is likely that any flooding from the trunk mains would flow into the WCML cutting and therefore not pose a significant risk of flooding to the Proposed Scheme.

6.6.5 There is a 1067mm diameter water main located within Abbey Road and a 406mm diameter water main located within Kilburn High Road. The Proposed Scheme will be in tunnel beneath both roads with no above ground infrastructure proposed in the area. The risk of flooding to the Proposed Scheme from these water mains is therefore low.

6.7 Summary of baseline flood risk

Table 4: Summary of baseline flood risk for all sources of flooding in CFA3

Source of flooding	Location of flooding source	Flood risk category	Elements at risk	Assessment of risk
Surface water	WCML and LO track beds on approach to Euston Station and at South Hampstead Station	High Drain London 30 years >0.3m	Adelaide Road vent shaft	Vent shaft will be >1m above ground level in risk area - no risk
			Alexandra Place vent shaft	Vent shaft will be >1m above ground level in risk area - no risk
			Euston tunnel	Proposed Scheme will be in tunnel - no risk
Artificial Sources	Finchley/Avenue Road (B511/A41) Trunk Water Main	Low Pathway present	Alexandra Place vent shaft	WCML cutting will lie between the source and the vent shaft and is likely to intercept flood flows - low risk
			Euston tunnel	Proposed Scheme will be in tunnel - no risk

7 Flood risk management measures

7.1 Risk of flooding from watercourses

7.1.1 There will be no risk of flooding from rivers to the Proposed Scheme, nor any anticipated effects on the risks of flooding from rivers within the study area arising from the Proposed Scheme. Therefore no specific mitigation will be required.

7.2 Risk of flooding from surface water

7.2.1 The risk of flooding from surface water runoff will be managed by attenuating peak surface water runoff from above ground infrastructure before discharging to TWUL sewers at restricted rates.

7.2.2 There will not be a significant risk of flooding from surface water sources to the Proposed Scheme within CFA3. Therefore no specific mitigation will be required.

7.3 Risk of flooding from groundwater

7.3.1 There will be no risk of flooding from groundwater to the Proposed Scheme, nor any anticipated effects on the risks of flooding from groundwater within the study area arising from the Proposed Scheme. Therefore no specific mitigation will be required.

7.4 Risk of flooding from drainage systems

7.4.1 There will be no risk of flooding from drainage systems to the Proposed Scheme, nor any anticipated effects on the risks of flooding from drainage systems within the study area arising from the Proposed Scheme. Therefore no specific mitigation will be required.

7.5 Risk of flooding from artificial sources

7.5.1 There are no instances where the Proposed Scheme will be at significant risk of flooding from artificial sources within CFA3. There will be no significant effects on the risk of flooding from artificial sources arising from the Proposed Scheme within CFA3. Therefore no specific mitigation will be required.

8 Post-development flood risk assessment

8.1 Local receptors

8.1.1 In addition to the risk of flooding that exists to the Proposed Scheme, there is potential for the Proposed Scheme to affect the risk of flooding to third party receptors by altering flow mechanics across the range of flood sources. All local receptors with a potential flood risk are identified in Section 5.2 of this report. For the Proposed Scheme to have an impact on a given receptor the identified pathway for that receptor must be shared by both the subject receptor and the Proposed Scheme with the result that a number of cases can be excluded immediately. Table 5 summarises the shared pathways between the Proposed Scheme and each receptor, and identifies cases where no shared pathway exists.

Table 5: Shared flood risk pathways in CFA3

Local receptor	Vulnerability classification as per the NPPF	Pathway	Shared pathway between Proposed Scheme and receptor
Primrose Hill urban centre	More vulnerable	Surface water 30 years - shallow.	No shared pathway.
WCML and LO	More vulnerable	Surface water 200 years - deep.	Adelaide Road vent shaft.
South Hampstead urban centre	More vulnerable	Surface water 200 years - deep.	No shared pathway.
South Hampstead Station	More vulnerable	Surface water 200 years - deep.	Alexandra Place vent shaft.
Quintin Kynaston School	More vulnerable	Surface water 30 years - shallow.	No shared pathway.
St John's Wood urban centre	More vulnerable	Surface water 200 years - shallow.	No shared pathway.

8.1.2 There is also the potential for the Proposed Scheme to change the baseline risk of flooding described in the Section 6 of this report. Though designed such that the probability of the Proposed Scheme flooding in any given year is less than 1 in 1,000, any change to the baseline risk of flooding could impact on the assessment of flood risk to the Proposed Scheme. All cases of flood risk discussed in Section 6 of this report are therefore reconsidered regardless of the presence or otherwise of third party local receptors.

8.2 Impact on risk of flooding from watercourses

8.2.1 The Proposed Scheme will not cross any Environment Agency designated main rivers or ordinary watercourses within CFA3 so the Proposed Scheme will therefore not lead to a change in the risk of flooding from rivers.

8.3 Impact on risk of flooding from surface water

8.3.1 Any above ground infrastructure has the potential to alter overland flow routes thereby changing the risk of flooding to local receptors through displacement of flood waters and alteration to flow conveyance times. The two proposed vent shafts within CFA3 lie close to areas of significant surface water flood risk and therefore have the potential to alter the risk of flooding in the area.

Adelaide Road vent shaft

8.3.2 Above ground construction at the Adelaide Road vent shaft will be confined to the area bounded by Adelaide Road to the north and the existing railway to the south. The proposals will not extend beyond the retaining wall at the edge of the existing railway cutting where the most significant areas of surface water flooding are predicted. There will be no construction within the area at risk of surface water flooding and there will, therefore, be no impact due to alteration of overland flow routes on the risk of surface water flooding in the study area arising from the proposed vent shaft.

8.3.3 Surface water will be collected and attenuated prior to discharge at an assumed rate of 34l/s to the existing TWUL 1,093mm diameter brick sewer on Adelaide Road. Attenuation volumes up to a maximum of 120m^3 are proposed in the vicinity of the shaft to attenuate storms up to the 1 in 100 years return period (1% annual probability) rainfall event including an allowance for climate change. Any connection and allowable discharge rates will be agreed in advance with TWUL.

8.3.4 The Proposed Scheme will not significantly affect the risk of surface water flooding at or in the vicinity of the Adelaide Road vent shaft.

Alexandra Place vent shaft

8.3.5 Above ground construction at the Alexandra Place vent shaft will be confined to the area bounded by the WCML to the north, Loudoun Road to the east, Alexandra Place to the south and Langtry Walk to the west. The proposals will not extend beyond the retaining wall at the edge of the existing WCML cutting where the most significant areas of surface water flooding are predicted. There will be no construction within the area at risk of surface water flooding and there will, therefore, be no impact due to alteration of overland flow routes on the risk of surface water flooding in the study area arising from the proposed vent shaft.

8.3.6 Surface water will be collected and attenuated prior to discharge at 34l/s to the existing TWUL 1,168mm diameter brick sewer on Alexandra Place. Attenuation volumes up to a maximum of 55m^3 are proposed in the vicinity of the shaft to attenuate storms up to the 1 in 100 years return period (1% annual probability) rainfall event including an allowance for climate change. Any connection and allowable discharge rates will be agreed in advance with TWUL.

8.3.7 The Proposed Scheme will not significantly affect the risk of surface water flooding at or in the vicinity of the Alexandra Place vent shaft.

8.4 Impact on risk of flooding from groundwater

8.4.1 The Proposed Scheme will not penetrate the water bearing chalk strata within CFA3. There will, therefore, be no impact on groundwater levels and consequently no effect on the risk of flooding from groundwater within the study area.

8.5 Impact on risk of flooding from drainage systems

8.5.1 Connections to the foul and surface water sewer network from the vent shaft headhouses within CFA3 will be agreed with TWUL in order to avoid creating additional burden on the existing public sewer network. There will not be a significant increase in the area of impermeable surface following construction as the sites are currently developed. The Proposed Scheme will, therefore, not lead to a change in the risk of flooding from drainage and sewer systems within the study area.

8.6 Impact on risk of flooding from artificial sources

Canals

8.6.1 The Proposed Scheme will be in tunnel where it will pass beneath the Grand Union Canal (Regent's Canal). The canal is at or below ground level in the vicinity of the Proposed Scheme and any ground settlement arising from the Euston tunnels is unlikely to increase the risk of flooding from the canal. The Proposed Scheme will, therefore, not lead to a permanent change in the risk of flooding from canals.

Reservoirs

8.6.2 The route will not cross any areas at risk of flooding from reservoirs. There will, therefore, be no effect on the risk of flooding from this source as a result of the Proposed Scheme.

Water mains

8.6.3 The settlement of the ground along the length of all water mains due to tunnelling and the potential damage to the pipes due to additional strain in the material will be assessed prior to and during construction. Although an increased risk of failure exists during construction this will be managed as part of the construction program. As long as the construction risks are appropriately managed the risk of failure of these water mains in the permanent case will not be increased as a result of the Proposed Scheme.

8.7 Summary of potential impacts and effects on flood risk

Table 6: Summary of potential flood risk impacts and effects in CFA3

Receptor	Vulnerability classification	Pathway	Impacts and effects
General Proposed Scheme	N/A	Rivers	No effects expected.
		Surface water	No above ground development within areas at risk and rainfall to be collected, attenuated and discharged to existing sewerage infrastructure. No significant effects expected.
		Groundwater	No effects expected.
		Drainage systems	Surface and foul discharges at vent shafts will be collected, attenuated and discharged to existing sewerage infrastructure. No significant effects expected.
		Artificial sources	No effects expected.
WCML and LO	More vulnerable	Surface water 200 years - deep	Adelaide Road vent shaft will not lie within the area at risk of flooding and will therefore not affect the risk of flooding in the area.
South Hampstead Station	More vulnerable	Surface water 200 years - deep	Alexandra Place vent shaft will not lie within the area at risk of flooding and will therefore not affect the risk of flooding in the area.

9 Conclusions

9.1 Summary

9.1.1 The Proposed Scheme within CFA3 extends from the A4201 Parkway to the A5 Kilburn High Road. The study area extends a distance of 500m from the Proposed Scheme and includes:

- areas at risk of surface water flooding in Primrose Hill, South Hampstead, and St John's Wood; and
- areas at risk of flooding due to the failure of trunk water mains.

9.1.2 The Proposed Scheme will either be in tunnel or at least 1m above design flood water levels within all areas at risk of flooding. Residual risks from these sources will be negligible.

9.1.3 CFA3 is heavily urbanised and has substantial residential and industrial areas within the study area. There are areas at risk of flooding as a result of direct runoff in rainfall events as well as overloaded sewers and failed water mains. All above ground construction will lie outside of the areas at risk and consequently will have no direct impact on the risk of flooding. Surface water runoff at the two vent shafts will be collected, attenuated and discharged to existing sewers at pre-agreed rates. This will not create an additional burden on the existing drainage infrastructure. The condition of trunk sewers and water mains will be monitored prior to and during construction to ensure no increased risk of failure due to settlement arising from the proposed tunnels. There will be no increased risk of failure to underground surface water infrastructure from the Proposed Scheme in the permanent case.

9.1.4 There will be no significant increase in the risk of flooding to third party receptors arising from the Proposed Scheme.

9.2 Residual flood risks to the Proposed Scheme

9.2.1 Residual flood risks arise in situations that are not included in standard design scenarios; for example, when a culvert becomes blocked causing flooding upstream. All design is generally undertaken assuming that existing infrastructure is functioning under normal conditions. There may, consequently, be areas where the potential severity of flooding may exceed the design standard under certain circumstances.

9.2.2 The Proposed Scheme will be in tunnel throughout CFA3. There will be no residual risk of flooding to the below ground components of the scheme. There are, however, potential residual risks to the two above ground vent shafts.

9.2.3 Blockage of underground surface water collections systems can cause surcharge and associated flooding. Both vent shafts are adjacent to the existing WCML cuttings. Any additional flooding arising from blocked sewers would be expected to flood the cuttings prior to ponding within any areas nearby. There will be no significant residual risk of flood waters ponding at either of the vent shafts as a result of blocked sewers in the area.

9.3 Residual effects of the Proposed Scheme on flood risk

9.3.1 The Proposed Scheme will not create an additional risk of blockage of sewer systems and will not lie within any area of significant risk of flooding. Surface and foul water discharges from the two vent shafts will be attenuated to avoid increasing the load on existing water collection systems. This will, therefore, not increase the potential effect of any residual flooding arising from blocked sewers and there will be no significant impact arising from the Proposed Scheme on the residual risk of flooding to third parties.

9.4 Compliance with local planning policy

9.4.1 The Proposed Scheme includes an allowance for future increases in the risk of flooding as a result of climate change by adding a 30% increase to rainfall intensities and flows in minor watercourses as recommended in the NPPF Technical Guidance document. Attenuation will be provided to ensure that the rate of runoff from permanent infrastructure, such as at the Adelaide Road and Alexandra Place vent shafts, will not increase as a result of the Proposed Scheme. This will ensure that there will be no increase in the risk of surface water flooding, especially in areas where a risk currently exists. The Proposed Scheme will be in compliance with the recommendations of the LBC SFRA, Core Strategy and adopted Development Policies.

10 References

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